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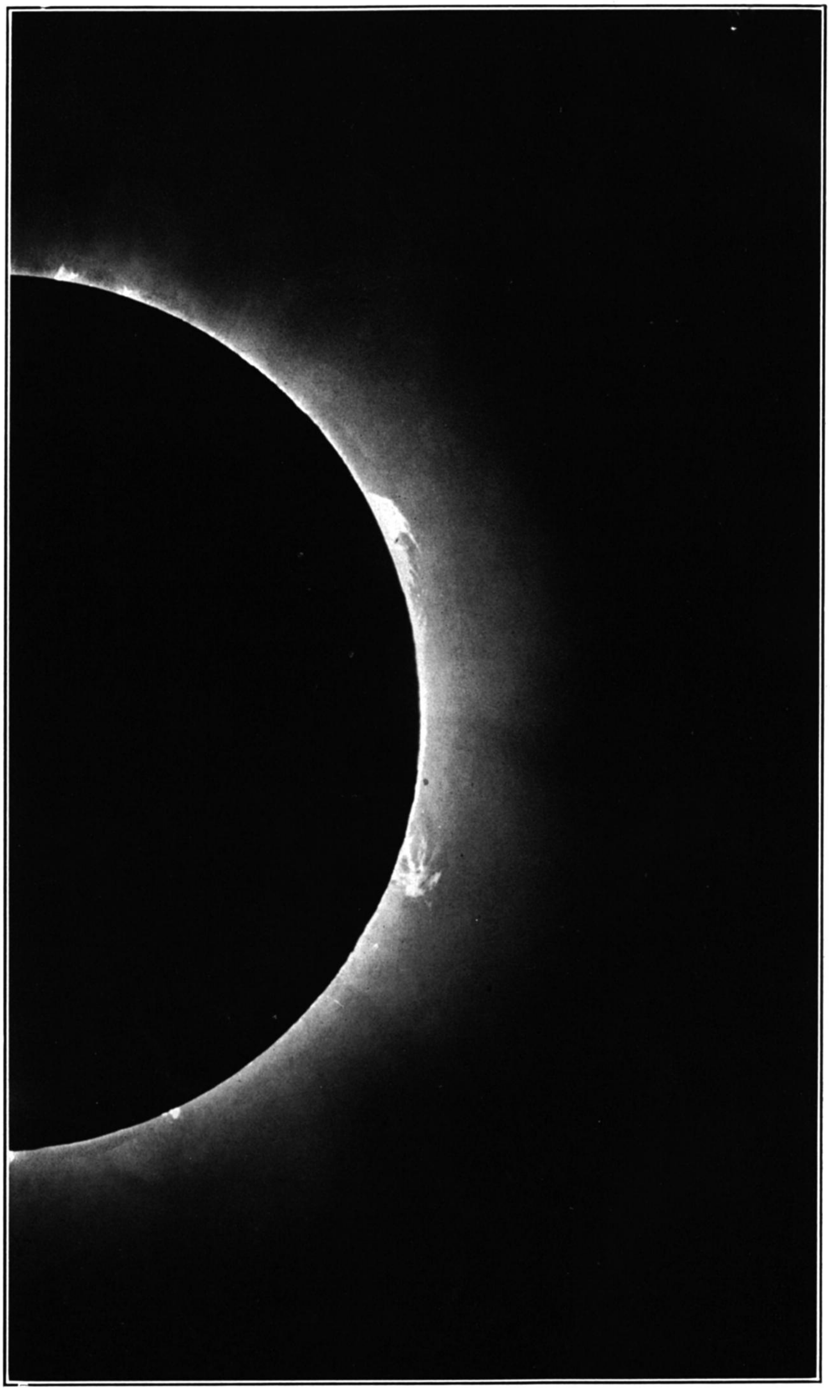

FIG. 1. THE INNER CORONA, WITH 40-FOOT CAMERA
Exposure 2 seconds at $1^m\ 50^s$–52^s of totality

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THE CROCKER ECLIPSE EXPEDITION FROM THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA

JUNE 8, 1918

By W. W. Campbell

The Lick Observatory had been hoping and fully expecting to observe the total eclipse of June 8, 1918, but plans as to instruments and observing program were held in abeyance until late in March, 1917, owing to uncertainty as to available instruments. As the readers of these *Publications* know, the extensive eclipse equipment of the Lick Observatory had to be left in Russia following the total eclipse of August 21, 1914. Thru the courtesy of the late Professor Backlund, Director of the National Russian Observatory at Pulkowa, and the kindly interest of General Nicolskoy, a high official of the Russian Government stationed in Kiev, our eclipse instruments and supplies were transported from Kiev via Moscow to Pulkowa, and stored there pending the termination of the war.

At various times during the following three years, and especially during the second and third years, Mr. Campbell wrote to Russia urging the return shipment of the instruments, but in these efforts he was disappointed. No action was secured until the middle of the year 1917, when Mr. A. G. Freeman, a prominent citizen of California, with business interests in Russia, arrived in Petrograd. The University of California authorities had supplied him with the necessary credentials to comply with all governmental formalities in starting the instruments homeward. The Imperial Academy of Sciences coöperated with Mr. Freeman, and the shipment left Pulkowa on August 15, 1917, via Siberia. A cable message from Vladivostok on December 15th announced the arrival of the shipment, including Professor Todd's Amherst College equipment, at that port. Mr. Freeman's firm kindly dispatched a cable message at once to Vladivostok, instructing as to the further shipment, and urging promptness. We were unable to obtain additional information concerning the shipment, until, on March 22, 1918, the cables brought the news that the business boycott at Vladivostok had finally been raised and the instruments would be shipped in the week March 24th to 31st by Russian Government steamer to Kobe, Japan. Instructions were wired to the Kobe agents of the steamers operating between Kobe and America to secure and transport the instruments at the earliest possible date. The shipment was still at Kobe on the tenth of May, and there seemed no hope that it would reach the United States in time for service on June 8th. A message received in San Francisco about June 20th gave hope, but not information, that the shipment would leave Kobe about that time for a Canadian port. Whether, upon arrival there, the instruments will be nearer home than they were in Kobe, is not a subject for expression of definite opinion.

The financial needs of the proposed expedition were outlined to Regent William H. Crocker late in the month of March. He at once offered to meet the expenses, as he had so generously done for many earlier expeditions.

The continued hope that the special eclipse equipment would return from Russia in time for use on June 8th had prevented us from purchasing substitute instruments, and from borrowing and adapting lenses, prisms, etc., available in other parts of this country. It was not until the first of April that we proceeded to prepare such instruments as the portable equipment of the Lick Observatory and other departments of the University would make possible. Dr. E. P. Lewis, Professor of Physics in the University of California, was invited to join the expedition, and use any equipment that his department could supply on loan. At the same time Professor Leuschner, Director of the Students' Observatory, most generously placed at our service any and all parts of the equipment of his department which could be adapted to our requirements, and this offer was accepted as to several indispensable items: break-circuit chronometer, chronograph, sextant, theodolite, telescope driving clock, spectrograph slits, etc. A little later Professor Burckhalter, Director of the Chabot Observatory, Oakland, offered the use of the two Brashear photographic lenses, aperture four inches, focal length approximately fifteen feet, which he had employed at the Georgia eclipse of 1900, and these we gladly accepted. We beg to express our obligations to Professor Leuschner and Professor Burckhalter for their kind offers.

The choice of an observing station was limited by the Cascade Mountains in the State of Washington on the west, and by the Rocky Mountains in Colorado on the east. The liability to coast fogs west of the Cascades, the distance to the trans-Rocky Mountain region and the low altitude of the eclipsed Sun in that region fixed these limits. The "Average Weather Conditions in June" supplied by Professor Marvin, Chief of the U. S. Weather Bureau and published by the U. S. Naval Observatory in a Supplement to the *American Ephemeris*, 1918, showed apparently that prevailing weather conditions are about uniformly good in early June at all points between these limits. If the choice were merely one of atmospheric conditions we should have decided in favor of an observing station in southeastern Idaho or southwestern Wyoming, rather than in Washington, Oregon or western Idaho, because of the risks one must run from forest-fire smoke in the latter region. Another factor influenced the decision. The continuing possibility that the instruments would arrive from Russia a few days or a few weeks before the critical date was a strong influence in favor of a station as close as practicable to the Pacific Ocean, in order that the belated shipment, if it arrived at the eleventh hour, might reach its final destination in the minimum time. The forest fires, for which the northwestern states are noted, are not presumed to be plentiful in the first half of June, tho they are a decided risk. After careful consideration it was decided to locate the station at or near Goldendale, Washington. This attractive village, of 1200 population, is situated at the end of a branch railway, thirty or forty miles east of the Cascade range and ten miles north of the Columbia River. The maps place it very close to the central line of the eclipse shadow path. For passengers it is but five or six hours from Portland, Oregon. The altitude of Goldendale is approximately 1600 feet above sea level. The region is devoted to agriculture, chiefly wheat-raising.

Mr. Campbell, on April 28th and 29th, was able to combine a visit to Goldendale, for the making of preliminary arrangements, with an extensive journey thru the northwestern states. Thru great good fortune and the public spirit and generosity of Mr. and Mrs. E. R. Morgan (Mrs. Morgan was the first person whom he chanced to meet in Goldendale), he was able to make exceedingly comfortable living and working arrangements for the expedition. The Morgan home is located a half mile outside the edge of the village, to the southwest, and Mr. and Mrs. Morgan offered to vacate their large and well-furnished residence and rent it for the use of the expedition. The instruments could be set up on the lawn adjoining the house. There was a large up-ground cellar, with thick walls, double doors and extensive shelving on two sides, which would make a commodious and model dark room just as it stood. There was an adjoining building available as a workshop. The residence was lighted by electricity from the village plant, and supplied with excellent water from the village system. Here were all the elements for an eclipse experience de luxe. The offer of the residence and premises was immediately accepted.

The instrumental equipment of the expedition was made ready in great haste between the first of April and the middle of May. Mr. and Mrs. Campbell, and Mr. J. E. Hoover, foreman of the Observatory workmen, reached Goldendale on May 20th, and found the instruments already there. Dr. H. D. Curtis and Dr. E. P. Lewis arrived on May 22nd; Dr. J. H. Moore on May 23rd; Mrs. Moore on May 31st; Miss Leah B. Allen, of the Department of Astronomy in Wellesley College, and Miss Estelle Glancy, Assistant in the Argentine National Observatory, at Cordoba, on June 4th; Professor S. L. Boothroyd, of the University of Washington, Seattle, and Mr. A. H. Babcock, Consulting Engineer of the Southern Pacific Company, San Francisco, on June 5th; Dr. John A. Brashear, Allegheny, Pennsylvania, and Dr. Ambrose Swasey, Cleveland, Ohio, on June 6th; and a number of other astronomers whose coming had not been formally announced, but who took valued part in the eclipse observations, on June 7th and 8th. The expedition had the great pleasure of receiving as guests, on June 7th and 8th, Mr. and Mrs. William H. Crocker and Mr. F. W. Bradley of San Francisco.[1]

The conveniences and comforts at the eclipse station and the excellent and experienced assistants made for rapid progress in the mounting, adjusting and testing of the instruments. Supplies of all kinds and labor were obtainable in Goldendale. As to ease of preparation and shortness of working hours, this expedition from the Lick Observatory was in a class by itself. There were no worries save those proceeding from atmospheric conditions.

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[1] The group of observers and guests reproduced in Figure 2 includes (reading from the left) Dr. Moore, Kathryn Moore, Mr. Babcock, Dr. Swasey, Prof. D. Campbell, Mrs. W. W. Campbell, Dr. Lewis, Mr. W. H. Crocker, Mr. Hoover, Mrs. W. H. Crocker, Mr. Bradley, Dr. W. W. Campbell, Prof. Boothroyd, Mrs. Plaskett, Dr. Curtis, Miss Glancy, Dr. Plaskett, Dr. Brashear, Dr. Young, Mrs. Moore, Miss Allen, Dr. Fath and Mrs. Morgan.

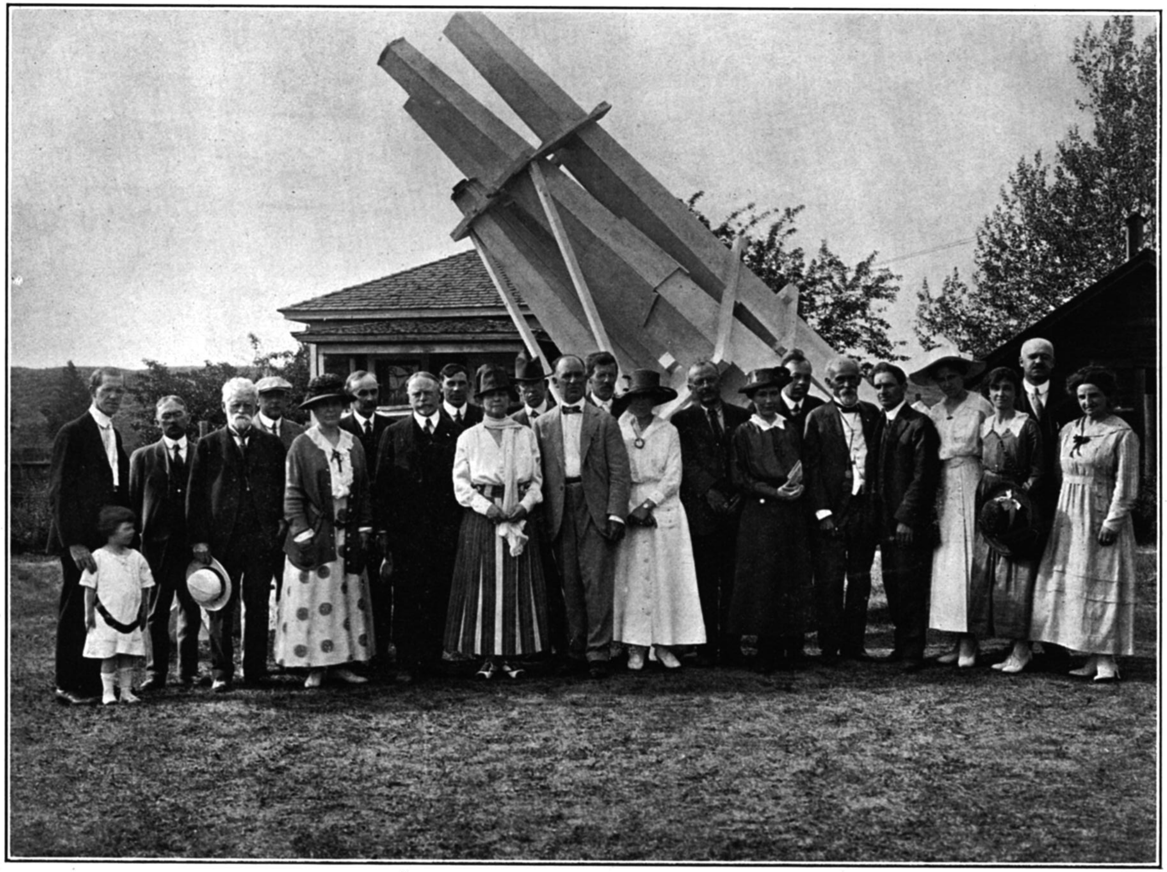

FIG. 2. THE OBSERVERS AND GUESTS
(The Vulcan-Einstein cameras in background)

There were a good many afternoons in the three weeks of our stay when the wind velocities were high and the air, both the higher and the lower strata, was full of flying dust. These conditions had a tendency to reach their maximum about the middle of the afternoons. The total eclipse was due to occur at 4:00 p. m., Rocky Mountain time; that is, 2:57 local mean time. The weather observations of the preceding years, as reported by the Weather Bureau, had not been made at this time of the day and they accordingly did not describe this peculiarity. Our expedition to Russia in 1914 was the victim of a somewhat analogous condition: the mornings and evenings—when the Government weather observations had been made—were remarkable for their beautifully clear skies, but the cumulus clouds formed every day and reached their maximum, at least during the last four weeks that our expedition was in residence, at the eclipse hour, about 2:50 p. m. The Russian experience naturally led us to fear that our plans for the afternoon of June 8th, 1918, might come to naught from the diurnal factor of wind and dust which the weather observations had not included. However, these fears did not materialize, as will be explained in the sequel. We dwell on them here merely to emphasize the opinion that the weather conditions along the eclipse paths of the future should if possible be observed not only in the mornings and evenings, in accordance with formal prevailing programs, but at the precise hours of the day when the eclipses will occur. It would be well if a special service, with this end in view, could be organized two or three or four years in advance of each observable eclipse.

The local times at the station were obtained from sextant observations of the Sun, made by Messrs. Campbell and Curtis. The longitude of the station was determined by comparing the local times with the time signals which came to Goldendale daily from Northfield, Minnesota, over the telegraph line of the railway, and, during ten days, more or less, preceding June 8th, from Mare Island, California. The railway station was more than half a mile from the eclipse station and it was necessary to transport the chronometer back and forth over a rough temporary road. The comparisons were made on ten occasions, and the longitude was determined to be $8^h 3^m 21^s.5 \pm 0^s.1$. The large-scale map accompanying the *Nautical Almanic Eclipse Supplement* assigned to our station, which was 0.9 mile west and 0.5 mile south of the business center of Goldendale, a longitude of $8^h3^m40^s$. The discrepancy was unexpectedly large.

The latitude of the station was determined from sextant observations of *Polaris* and of the noon Sun, and the result came out $+ 45° 48'.9 \pm 0'.1$. This agreed well with the eclipse map.

According to the *Nautical Almanac* data, the eclipse would be central at our station at Greenwich mean time $11^h0^m12^s$. The latitude assigned by the *Nautical Almanac* to the point on the central line of the shadow whose longitude is $8^h3^m21^s.5$ is $+ 45° 48'.83$. It thus appears that our observing station was situated about four hundred feet north of the central line of totality, as laid down by the *Nautical Almanac*. The uncertainty in the Almanac data is of course larger than this, but we may safely say that our station was very close to the central line of the shadow.

The instruments were mounted on the lawn, immediately west of the Morgan residence and about 140 feet north of the central line of the county road bounding the premises on the south.

The program of observations was gone thru a great many times from the afternoon of the 5th to the evening of the 7th, until each observer's part became essentially automatic.

The day of the eclipse will long be remembered by all who were connected with the expedition. The sky had clouded late on the night of the 7th, and we may say that it remained completely clouded until toward midnight of the 8th, with the important exception that a small rift occurred exactly at the critical time and place. The clouds uncovered the Sun less than one minute before the beginning of totality and they again covered the Sun a few seconds after the end of totality. The small region of unclouded sky containing the totally eclipsed Sun seemed to be absolutely clear, and the bluest sky we had seen during the whole of our residence at the station. Perhaps this intense blueness was a contrast effect. Equally important, the atmosphere during totality was very tranquil; the "seeing" was excellent. The rift in the clouds was not large enough to include the whole of the region surrounding the Sun covered by the so-called Vulcan and Einstein cameras, and two of the plates secured with those instruments were undoubtedly affected adversely. The program of observations went thru without apparent hitch, tho the value of the photographs secured with two or three of the eight instruments attached to the spectrographic polar axis was somewhat reduced by the unfortunate fact that the rate of the driving clock elected to change itself shortly before totality, probably thru the lodgment of dust or similar obstruction at some point in the clock train.

It is well known that the Moon does not follow precisely the path laid down for it in the *Nautical Almanac.* There is no disposition to question the precise validity of Newton's law of gravitation in this connection, but apparently some force as yet unrecognized by astronomers is operating to modify very slightly the Moon's motion. It is desirable that eclipse observers know whether the eclipse will come earlier or later than the predicted time, and it is possible to obtain this information. Several months ago Professor Tucker observed the position of the Moon with the meridian circle of the Lick Observatory, and found it very slightly ahead of the predicted place in its orbit. The discrepancy, he estimated, would cause the eclipse of June 8th to occur about twenty seconds of time earlier than the Almanac prediction. Our program of warning to the observers accordingly included this factor.

In the early morning of the 8th and again in the late afternoon the clouds covering the Sun were thin enough to let us secure poor time observations, but these were better than none at all. To make sure of our time we compared our chronometer at noon with the Mare Island time signals. The resulting longitude determination agreed within one-tenth of a second of time of the adopted longitude, and we therefore had confidence in the time determinations. The counting of the chronometer, in the hearing of all the observers, was conducted by Mrs. Moore; and the chronometer beats were also recorded electrically on a chronograph sheet. It was arranged that the signal "Go" for the instant of totality should be given by Mr. Campbell, who, with Professor Boothroyd as assistant, was operating the 40-foot camera. He could see the vanishing crescent, with great clearness, on the plate holder in the lower end of the camera, and on this account was perhaps better equipped than any of the other observers to estimate the precise instant when totality was complete. The crescent finally diminished in length very rapidly, and the signal was given when it was estimated that the shortening crescent should have vanished. This was done both orally, to start the chronometer count and the observing programs with all the other instruments, and additionally by pressing an electric key which broke the chronograph circuit and produced a corresponding signal on the sheet. Mr. Campbell had never operated the great coronal camera at preceding eclipses and he was surprised at the number and the intensity of the isolated brilliant points remaining at and near the central point of the vanished crescent. They were a temptation to delay in announcing that the instant of totality had come, but they were not allowed to affect the judgment. No doubt they were due to the solar rays which passed thru the deeper valleys on the edge of the Moon after the Moon's general contour had passed beyond the apparent edge of the Sun.

The reappearance of the crescent Sun was noted on the chronograph sheet by the pressing of the break circuit key, but as the observer's hands were busy with the last exposure when the first rays of the Sun returned, his signal was late by an amount estimated and recorded at once as one and one-half seconds of time.

As soon as possible after the signal "Go" had been given, Mrs. Moore counted seconds, beginning with "One," "Two," and so forth, continuously until a fraction of a minute after the totality had passed, when Mr. Campbell compared her count with the chronometer face; and the records were made accordingly.

The computed duration of totality was $1^m 57^s.3$. The duration recorded on the chronograph sheet after subtracting the estimated retardation of 1.5 seconds at the end of totality amounted to $1^m 57^s.4$.

The program of warning time signals prepared two hours in advance of the total phase had fixed upon a certain hour, minute and second of the chronometer reading for totality to begin. Totality came two seconds later than the chronometer time set down for it to occur. A re-reduction of the longitude observations after returning to Mount Hamilton decreased our predicted time of totality by one second. The total phase of the eclipse therefore occured three seconds later than our prediction; that is, seventeen seconds of time in advance of the *Nautical Almanac* prediction.

The comparison of Mrs. Moore's counts with the chronometer face checked perfectly with the chronograph record as to the beginning of totality. The ending of totality was estimated by several observers in terms of Mrs. Moore's counts. Their observed durations average $1^m 57^s$, and their estimated time of the return of the crescent Sun agreed within a second with the chronograph determination.

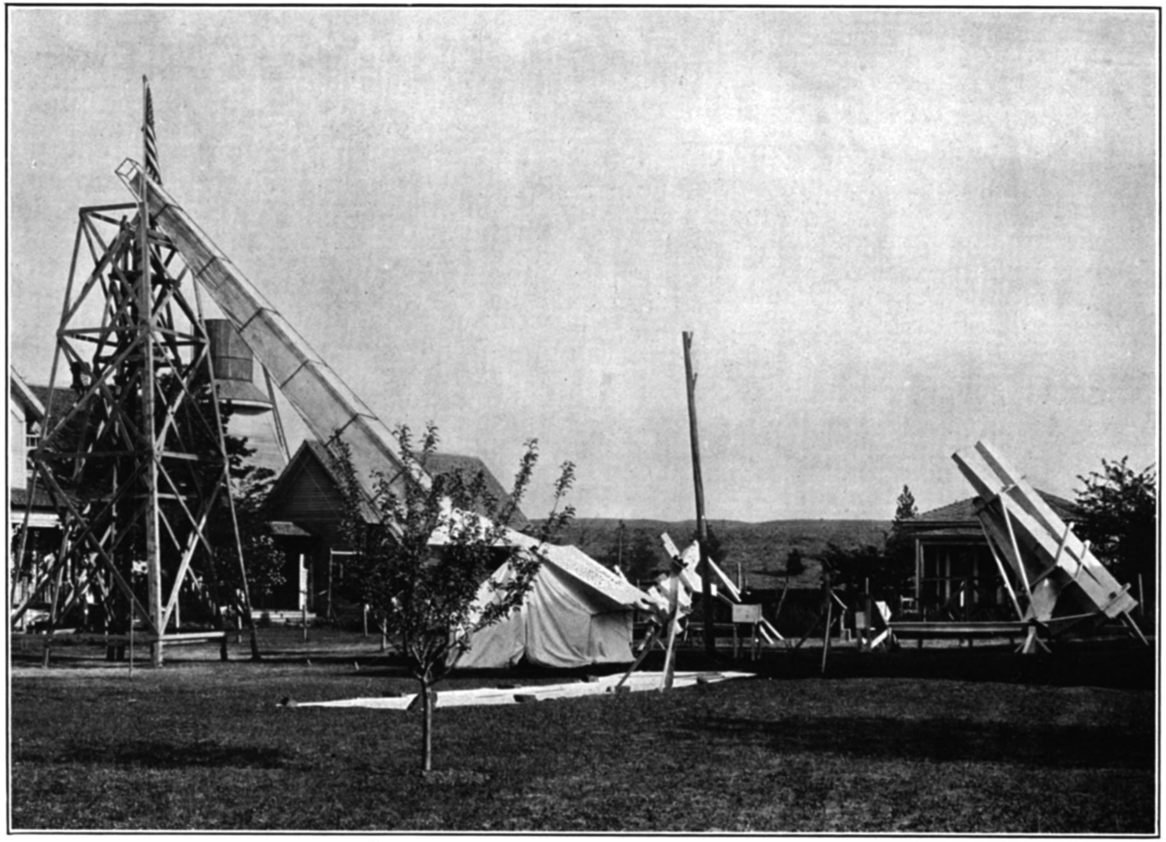

FIG. 3. THE CROCKER ECLIPSE EXPEDITION
Goldendale, Washington, June 8, 1918

The details of the time and longitude determination will be published later in a Lick Observatory Bulletin. It is sufficient here to say that the running of the chronometer was remarkably uniform. Many of the longitude determinations were made when high winds disturbed the mercurial horizon, or thin clouds covered the Sun, but the results are sufficiently numerous and accordant to be absolutely trustworthy.

The latitude determinations were subject to some uncertainty, as the altitude of the Sun when on the meridian was too great for the making of satisfactory sextant observations. The solar rays made large angles of incidence and reflection with the sextant mirrors, and the solar images were appreciably deformed, owing to imperfections or strains in the mirrors. However, the results obtained from the Sun in the south and from Polaris in the north are in good accord.

The Lick Observatory possessed a Brashear photographic lens purchased in the early nineties by Director Holden, aperture 6 inches and focal length 40 feet. Professor Holden had intended to substitute this lens for the Clark lens, 5 inches aperture and 40 feet focus, in the photoheliograph camera at Mount Hamilton, whenever the Clark lens would be absent on eclipse service, but the Brashear lens had never been used. It was mounted on the outside of the 36-inch telescope tube at Mount Hamilton early in April, 1918, and found to give excellent definition, as we had fully expected. A canvas tube and its supporting framework of iron pipes, and likewise the steel track and steel plate-carriage of a 40-foot camera, as used at the eclipse of 1905 in Labrador, were still in existence here. Very little work was required, therefore, to complete the equipment of a 40-foot coronal camera in accordance with the plans of its original designer, Professor Schaeberle. A pyramidal tower 32-feet high to support the 6-inch lens in a fixed position, and a surrounding tower, canvas-covered to protect the inner tower from wind vibrations, were constructed of 1-inch by 4-inch lumber secured at Goldendale.

One of the Vulcan lenses, aperture 3 inches, focal length 11 feet 4 inches, used at the Flint Island eclipse of 1908, had not been taken to Russia. A photographic lens, aperture 4¼ inches, focal length 15 feet, corrected for the photographic region, was also available. It was decided to provide tubes for these lenses and for the two Chabot lenses, and mount the four on a separate polar axis, for recording the brighter stars in the region immediately surrounding the Sun, in the expectation that the so-called Einstein effect could be tested, and that any existing unknown bright objects in the vicinity of the Sun would be recorded.

Spectrographs, polarigraphs, and two cameras for recording the corona on a smaller scale were made ready as described below. The opportunities of the eclipse station were made available to Miss Glancy to photograph the Sun's surroundings thru a relatively large aperture and a variety of absorbing screens in accordance with plans prepared by Director Perrine of the Argentine National Observatory.

Forty-Foot Camera

W. W. Campbell, Observer; S. L. Boothroyd, Assistant

Ten exposures varying from short as possible up to 32 seconds were secured, but the last one, a "short as possible," on a process plate, was exposed just at the instant when the crescent Sun reappeared. The darkness in the 40-foot camera, apparently owing to the unusual darkness of this eclipse, was greater than we had anticipated, and on that account Mr. Campbell's motions were slower than they had been in the practice programs; hence the belated exposure of the tenth plate. When the plates had been developed it was found that all parts of the mechanism had worked perfectly and that all of the plates had the benefit of excellent focus and magnificent seeing. It is thought that the coronal streamers are depicted in greater sharpness than at any preceding eclipse observed by the Lick Observatory. A slight peculiarity in the holding of the lenses of the objective in their metal cell did not affect the defining power, but did cause a "ghost" on the photographic plate. This false image is mingled with some of the coronal streamers on the longer exposures, but on all the shorter exposures the ghost fortunately falls either upon the Moon's image or beyond the outer ends of the recorded streamers. The scientific values of the plates are not reduced in any way and the pictorial effect is modified only for the longer exposures. An attempt is made to reproduce by half-tone process a section of one of the large-scale coronal photographs. It should show beautifully some large prominences at the edge of the Sun and series of sharply curved coronal streamers which completely encompass the prominences as hoods. Unfortunately, and as we have so often found by trial, an adequate method of reproducing solar coronas in print has never been found. One must go to the original negative, or to photographic copies on glass.

The prominences at the edge of the Sun are large, but not exceptionally so, but of course they were very interesting and striking to those who observed them visually. We did not plan to observe them technically, as they are available to every-day observation at home by the means of suitable spectroscopes. The corona, as recorded by the 40-foot camera, was remarkable for the sheaths of streamers which surrounded all of the principal prominences. This structure had been observed at earlier eclipses, beginning perhaps with the Indian eclipse of 1898, but they were especially extensive and well defined at the recent eclipse. After observing them with care it seems impossible to question that the forces in the Sun responsible for the prominences are the forces which are responsible for the coronal streamers situated near the prominences.

Vulcan and Einstein-Effect Cameras

H. D. Curtis, Observer; J. E. Hoover, Operating Exposing Shutters

The two Chabot photographic lenses, aperture 4 inches and focal length 15 feet, were attached to a polar axis of the well-known box form, shown, at the right, in Figure 3. The tubes for these were constructed of wood at the eclipse station by Mr. Hoover. They were mounted with their axes parallel to each other and pointing to the center of the Sun. The 4¼ inch aperture, 15 feet focus photographic lens, belonging to the Observatory, and one of the so-called Vulcan lenses, aperture 3 inches, focal length 11 feet 4 inches, were provided with suitable tubes and mounted on the same polar axis. The axis of the latter tubes were directed one to the west of the Sun and the other to the east of the Sun, so that the areas recorded by their photographic plates would overlap the west and east edges of the area recorded with the Chabot cameras in amount 1 inch, respectively. The four tubes were rigidly bound together, and the driving arm connecting the clock with the polar axis was rigidly connected with the system of tubes. The driving clock was rated to follow the stars and not the Sun. 14 x 17 inch plates were used and only one exposure, beginning at count 3 seconds and ending at count 1 minute 55 seconds, was made with each camera.

The corona was of course recorded with the Chabot lenses, in the center of each plate, but the trailing in the east and west direction is perceptible owing to the stellar rate of driving.

Mr. Curtis has given the plates only a hasty examination, as he was at home but a few days following the eclipse before taking up his residence in Berkeley for war service. He reports that stars fainter than the eighth magnitude are recorded, but that the clouds to the east and west of the clear sky immediately over and surrounding the Sun interfered somewhat with the recording of the fainter stars in the extreme east and west areas. No further statement as to these plates can be made at the present time.

Under normal conditions the region of the sky in which the Sun would be situated at the time of total eclipse would have been photographed by night at Mount Hamilton several months in advance of the eclipse date, in order to record the stars in that area when the rays of light proceeding from them would not be subject to the Einstein effect, and when any unknown bodies revolving around and in close proximity to the Sun would not be in that region. The failure of the eclipse instruments to return from Russia naturally prevented the carrying out of this logical program. The four instruments used at Goldendale have been returned in completeness to Mount Hamilton, and in the late fall or early winter they will be remounted and the duplicate star plates be secured. It is hoped that a comparison of objects photographed on the eclipse plates, with the objects recorded on the duplicate stellar plates, will furnish results on the questions involved. If the Einstein effect is a reality and the stellar images on the original and duplicate plates can be measured as to their positions with accuracy, then we should be able to make a statement as to the influence of the Sun's gravitational field upon the stellar rays which passed close to the Sun from seven to nine minutes prior to the time of mid-eclipse on June 8th. (Rays of light required about eight and one-half minutes to pass from the Sun to the observer.)

Forty-eight-Inch Coronal Camera

Mrs. Campbell, Observer

A camera of aperture 3 inches and focal length 48 inches was used to secure a series of eight exposures on the corona, with exposure times varying from 1 second up to 16 seconds. The images of

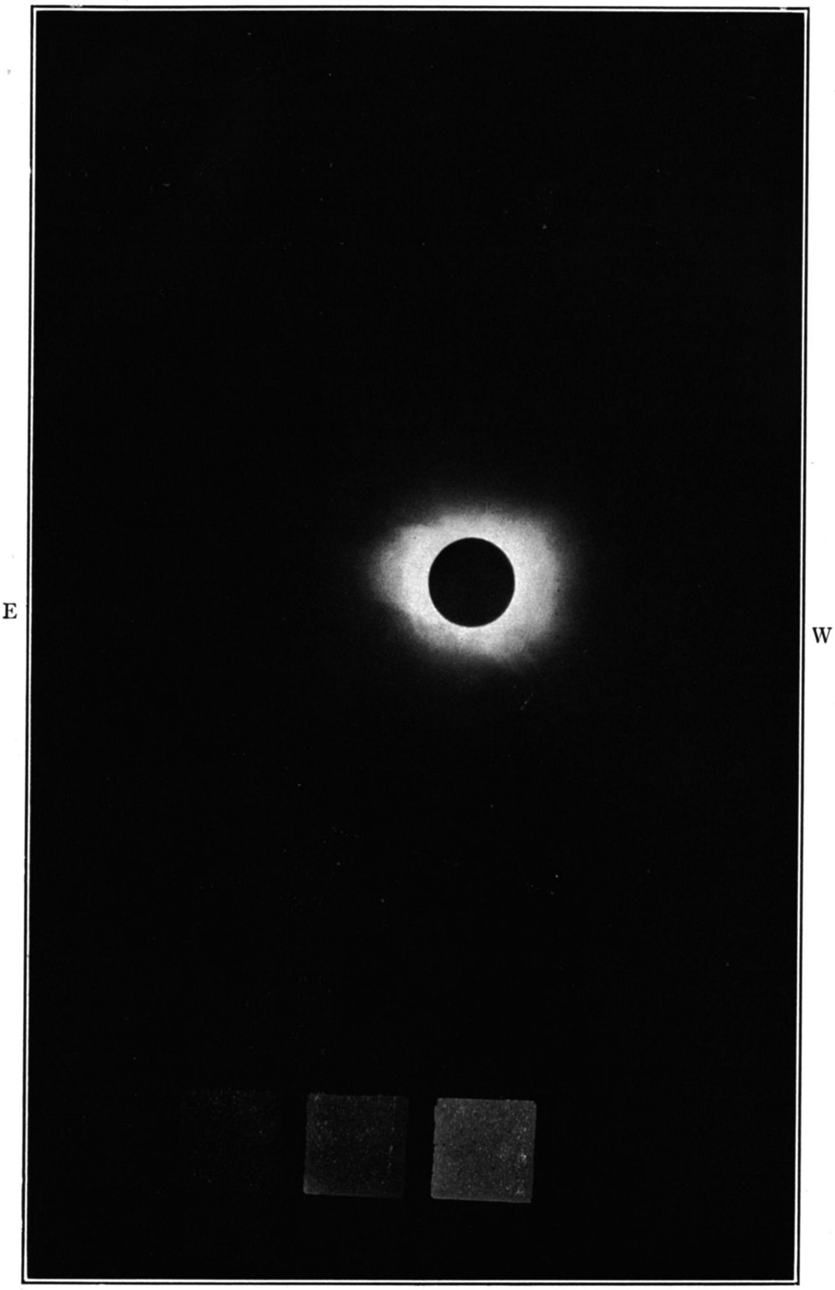

FIG. 4. THE SOLAR CORONA
(Focal length of camera, 48 inches)

the corona are good. A 4-second exposure is reproduced, imperfectly, in Figure 4.

This series of photographs show the general outline-form of the corona better than those secured with any of the other instruments.

ELEVEN-INCH CORONAL CAMERA

Miss Leah B. Allen, Observer

This camera, designed for landscape work, secured a series of eight coronal pictures with exposure times coincident with those of the 48-inch camera. Their purpose was to photograph the corona 'n as great extent as possible. The longest streamers recorded, those to the east of the Sun, approximate three solar diameters.

LICK OBSERVATORY SPECTROGRAPHS

J. H. Moore, Observer; A. H. Babcock, Assistant.

These instruments were attached to a po'ar axis of the usual box form.

Three-Prism Spectrograph

This instrument had the following optical parts:

Image lens, aperture 1½ inches, focal length 10½ inches, stopped down to angular diameter matching that of the collimator.

Collimator lens, aperture 1 17/32 inches, focal length 28½ inches.

Three prisms of Jena glass 0.102, angle 63½°; prisms set for minimum deviation at 5303A, with angle of deviation 171°12′.

Camera lens, aperture 1 31/32 inches, focal length 16 inches.

These optical parts were supplied with a wooden mounting designed by Dr. Moore and constructed at Mount Hamilton by Mr. Hoover.

The slit, belonging to the original 3-prism Mills spectrograph, was placed across the center of the Sun, east and west. The comparison prisms (Wright system) which limited the length of the slit were adjusted, as to their distance apart, so as to let coronal light from strata five or six minutes of arc deep both east and west of the Sun enter the slit. The iron spark was employed for comparison spectrum. It was inserted not only at the west and east end of the slit, but centrally on the slit. The resulting spectrogram contained the spectrum of the corona to the west of the Sun, the spectrum of the corona to the east of the Sun, a comparison spectrum of iron between the coronal spectra and two outer comparison spectra of iron.

The purpose of this 3-prism instrument was to determine as accurately as possible the wave-length of the well-known green line of coronium. A Cramer isochromatic instantaneous plate was used, and the exposure to the coronal spectrum extended from count 3 seconds to count 1 minute 55 seconds. The continuous spectrum of the corona and the bright green line are strongly recorded to the west of the Sun. They are only very faintly recorded to the east of the Sun, due in large measure, possibly entirely so, to a defect in the running of the driving clock, which caused a section of the diaphragm over the slit to obstruct the light from the eastern corona.

The spectrogram has thus far been measured by only one observer and the definitive wave-length of the green line will be published later. It will differ very little from 5303.0A.

One-Prism Spectrograph

This instrument had for its purpose the recording of the general spectrum of the corona. Its optical parts consisted of:

Image lens, aperture 1¾ inches, focal length 16 inches, stopped down to have the same angular aperture as the collimator lens.

Collimator lens, aperture 1½ inches, focal length 28½ inches.

Single light flint 60° prism, set for minimum deviation at Hγ.

Camera lens, aperture 2 inches, focal length 16 inches.

A Seed 27 plate was employed. The exposure to the coronal spectrum extended from count 3 seconds to count 1 minute, 55 seconds. The comparison spectrum with the solar crescent as origin of light was inserted between the spectra of the corona east of the Sun and west of the Sun, respectively, about twenty seconds after the end of totality.

The spectrum is well recorded for the corona immediately west of the Sun, but it is not so strong as we had expected and extends out to only six or seven minutes of arc from the Sun's western edge. The spectrum of the corona east of the Sun is recorded very faintly because of the defect in the clock driving, which caused the eastern coronal source of light to be obstructed by a diaphragm over the slit.

The coronal spectrum west of the Sun consists of continuous radiations without any evidence of absorption lines, and of at least five bright lines. These lines are at wave-lengths 5303, 4231, 4086, 3987, 3601A. Seven other bright lines are suspected.

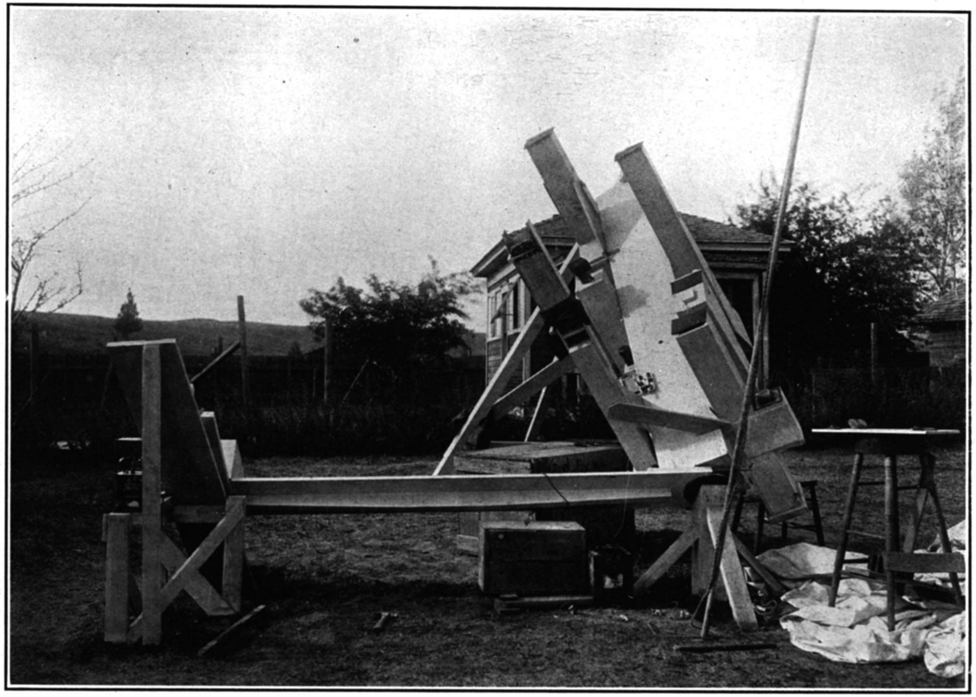

FIG. 5. THE SPECTROGRAPHIC POLAR AXIS

These results are in harmony with those secured by us at earlier eclipses, to the effect that the inner corona is radiating its own light and is not radiating reflected sunlight in extent sufficient to impress the absorption lines of the solar spectrum upon the coronal continuous spectrum. The absorption lines previously observed in the corona have always referred, I believe, to those parts of the coronal streamers situated further from the Sun than the region observed at the eclipse of June 8th. It is not clear to us why the coronal spectrum was not recorded to a greater distance from the Sun's edge. Scores of bright lines from a prominence on the west edge are duly recorded and there is no doubt that, so far as the diaphragm over the slit is concerned, the light from the western corona was not prevented from entering the spectrograph. A slit much narrower than we had intended to use would explain the result, but we have no other reason to think that the slit width changed from that which we had fixed with care several hours prior to the eclipse.

Objective-Grating Spectrograph

In this instrument the light of the corona fell directly upon a Rowland plane grating with ruled lines 2 1/16 inches long, covering a width of 3 3/16 inches, 14,438 lines to the inch. The rays diffracted by the grating passed thru a camera lens, aperture 2 9/16 inches and focal length 15 inches. A Cramer isochromatic instantaneous plate was used, and the exposure to the coronal light extended from count three seconds to count 1 minute 55 seconds. The grating was set to bring the green line of coronium 5303A in the third-order spectrum to the center of the photographic plate. A strongly-actinic section of the violet region of the fourth-order spectrum also fell upon the photographic plate. To eliminate the fourth-order spectrum from the photograph, an absorbing screen of green glass was placed three or four milimeters in front of the photographic plate.

The green coronal ring is sharply recorded on the negative as an elliptical ring, but the depth of the recorded stratum is not so great as we had anticipated. The distribution of the coronium materials around the Sun's edge is irregular. It is strong near the east and west edges of the Sun and fairly strong at the south edge of the Sun, but the section of the ring corresponding to the Sun's north edge is vacant.

PROFESSOR LEWIS'S INSTRUMENTS

E. P. Lewis, Observer; A. H. Babcock, Assistant.

These instruments were mounted on the polar axis, which also carried the Lick Observatory spectrographs.

Professor Lewis's preliminary report is here quoted:

"The instruments used by me were a large two-prism quartz spectrograph, for obtaining the coronal and flash spectra, a small three-prism quartz and fluorite objective prism spectrograph, with double-image prism, for studying possible polarization in the lines, and a double-image camera for studying the integral polarization of the corona.

"The large spectrograph was composed of two Cornu prisms of 6.8 cm. height and 9.6 cm. length of face, and two quartz lenses of 9.8 cm. diameter and one meter focal length, with a temporary wooden mounting. On account of curvature of the focal plane, films of dimensions 7½ by 3¾ inches were used.

"With a much shorter exposure, the spectrum of the corona is much brighter than that obtained at Flint Island. (I do not think this could have been due to the slit being wider than it was thought to be.) The latter, however, showed about fourteen strong coronal lines, while on the spectrogram obtained at Goldendale not more than two or three true coronal lines are to be seen. A number of prominence lines are found. It seems likely that this disappointing result was due to weather conditions on the Sun. The number of sunspots and prominences observed indicated great solar activity, which might be expected to project large quantities of solar matter into the upper atmosphere. If the continuous coronal spectrum is due to scattered light, this would account for the predominance of this over the line spectrum.

"On account of delay in exposure, only a few of the stronger lines of the first flash were obtained. In the spectrum of the second flash about 250 strong lines are to be seen. Their wave-lengths have not yet been determined.

"The objective prism spectrograph was composed of two small quartz Cornu prisms and a fluorite prism, a quartz lens of about 25 cm. focal length, and a double-image calcite prism of about one inch effective aperture placed in front of the prism train. A pile of three thin microscope cover glasses, which cut off little ultraviolet light, was likewise placed in front of the prism train in order to compensate the polarization produced by the prisms. Preliminary observations indicated that compensation was secured within about two per cent, but further measurements will be made to check this result. The double spectrum obtained was somewhat over-exposed. Only one coronal ring (or rather ellipse, on account of the inclination of the plate) was obtained, that of the green line. Very careful photometric measurements will be necessary to determine whether there is any polarization of this ring. It is hardly to be expected that polarization exists in the lines.

"The double-image camera was composed of a three-inch achromatic lens of 72 cm. focal length, with a double-image calcite prism of about 1¼ inches aperture in front of it. On account of the residual prismatic dispersion of the double-image prism, it was necessary to use color screens. Two exposures were made, one with a green, the other with a blue color screen. Only the latter was in good focus. A faint false image due to internal reflections makes exact measurement of relative intensities of the two images impossible, but it is very evident in both photographs that strong polarization existed out to the very limits of the corona as recorded on the plate, a distance greater than the solar diameter. This strengthens the view that condensed metallic vapors had been projected to great distances from the Sun."

Miss Glancy exposed five plates to the direct rays of the corona and the immediately surrounding sky, thru a variety of color screens, to isolate special regions of the spectrum. Their purpose is to determine the sum total of coronal radiations in the spectral regions employed. The photographs will be forwarded to Dr. Perrine at Cordoba for measurement there. We hope that the clouds east and west of the corona did not reduce the values of the plates.

A standard thermometer mounted out of doors in an ideal location was read by Mrs. Moore at 1:30, 2:30, 3:30, 4:30, 5:30, and 8:30 p. m. in the afternoons of June 5, 6, 7, 8, 9, and at approximately fifteen-minute intervals during the afternoon of the 8th. The mean results or the observed temperatures on the 5th, 6th, 7th and 9th are plotted in the upper curve of Figure 6, line cut. All of the readings made on the afternoon of the 8th are plotted along the full-line curve. The estimated normal curve for the afternoon of June 8th is r presented by the dotted line. The unexpectedly high readings at about 5 p. m. of the 8th may have been due to the much

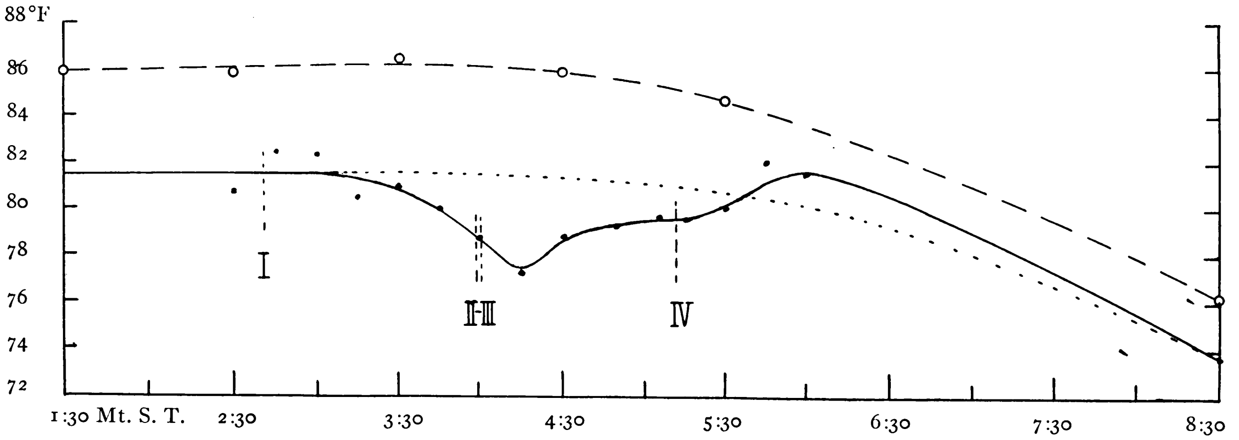

FIG. 6. TEMPERATURE CURVES AT GOLDENDALE, WASHINGTON

Broken line — — — — — — Mean temperature curve, June 5, 6, 7, 9.
Full line ———————— Observed temperature curve, June 8.
Dotted line .... Estimated normal temperature curve, June 8.
The four times of contacts are indicated by I, II, III, IV.

thinner clouds prevailing in the region of the Sun at that hour of the day. The maximum lowering of the temperature by the cutting off of the Sun's heat radiations during the eclipse appears to have been about four degrees Fahrenheit.

The expedition was extremely fortunate in having the volunteer assistance of several observers of great experience, who noted visually many interesting phenomena.

Some observers of earlier eclipses have said that visual observations of the inner corona show a vastly more complicated coronal structure than even the large-scale photographs of the corona reveal. This conclusion contains some elements of the unexpected, tho in the absence of personal experience we have not meant to question it seriously. Dr. Brashear and Dr. Swasey were requested to examine the inner corona with a small telescope which they brought with them, aperture 2 inches, and magnifying power 10, from this point of view.

Dr. Brashear's comment: "Turning to the telescope prepared for the observations of the inner corona, I noticed but little marked detail in the same."

Dr. Swasey's comment: "I could see no detail in the inner corona. It simply seemed to be rapidly more intense in brightness as it approached the Sun's limb."

Possibly the telescope was too small to make the test satisfactory.

Outline drawings of the visible coronal structure were attempted by Messrs. Brashear, Swasey, Douglas Campbell and Plaskett. The time was too short for the making of accurate drawings, and some of the observers found the prevailing darkness during totality so great that they could not see their drawings clearly enough to proceed.

The observers were asked to note the greatest visible extent of the coronal streamers.

Dr. Swasey estimated that the streamers east and west of the Sun had a length equal to one and one-half solar diameters.

Dr. Douglas Campbell (Professor of Botany, Stanford University) sketched the streamers to the east of the Sun to one and two-thirds solar diameters.

Dr. J. S. Plaskett (Director of the Dominion Astrophysical Observatory, Victoria, B. C.) estimated that the coronal streamers to the east of the Sun had a visible length of 2.3 solar diameters.

Another sentence in Dr. Plaskett's report says: "The corona extended to about two to two and one-half diameters of Sun, very intense toward the limb and decreasing rapidly in geometrical progression until about one-half of solar diameter outward from the Sun, and after that more slowly."

The eclipse shadow bands were observed in great definitiveness and considerable detail by six observers.

Dr. Brashear: "My observations of the shadow bands commenced when the time signal '30 seconds before' was called out. The bands were plainly seen, and, tho moving swiftly, I noticed they were brightest on the preceding side. The angle or direction of motion was so marked that it was readily defined on the white sheets of cloth by means of the straight rods of wood provided for the purpose. My observations were confined to their appearance before totality. The crest line of the waves defined by three rods and measured as to their azimuths after the passing of totality, were south 40½° west, south 38½° west, south 39° west; mean south 39.3° west. The shadows were moving from northwest to southeast."

Dr. Swasey: "The shadow bands were very plainly visible both before and after totality, perhaps best about a half minute before totality came, and about ten seconds after totality passed. They were traveling from northwest to southeast. The distance between the crests of the waves was estimated at about ten inches." The lines in Dr. Swasey's sketch representing the wave fronts are in azimuth approximately south 40° west.

Dr. Plaskett: "Shadow bands quite prominent, moving rapidly say ten feet per second, crests of waves about ten inches apart. Azimuth of wave crests south 55° west before totality, and south 45° west after totality. Moving from northwest to southeast. More prominent after than before totality."

Dr. Reynold Young (Chief Assistant in the Dominion Astrophysical Observatory): "Shadow bands near beginning of totality visible fifteen to twenty seconds before to two or three seconds after. Width of shadows estimated at two inches, dark, with no color; width of bright bands between shadows about six inches; therefore dark bands about eight inches apart. Moved from northwest to southeast at rate of three or four feet per second. The crests seemed broken more than could be accounted for by irregularities in white cloths spread on the ground. Bands not so plainly observed after totality was past. To me bands seemed about one inch wide when first visible, and fairly faint. As they grew plainer they seemed under two inches, and most plainly visible about two or three seconds before totality." The wooden rods laid down on the white sheets by Dr. Young to mark the line of wave crests were found, after totality passed, to be in position angles, before totality south 39° west, and after totality south 48° west.

Dr. E. A. Fath (President of Redfield College): "Shadow bands appeared at least one half minute before totality and continued to totality; then again immediately after close of totality and continued at least one half minute. Bands were approximately parallel and consisted of alternate bands of light and shade. Bands not sharply defined, and appeared of variable width in so far as the shadow part was concerned. Bands seen nearest beginning and ending of totality were best defined, the definition decreasing in quality in each direction from totality. Motion from northwest to southeast. Velocity one meter, more or less, per second, in a direction perpendicular to the bands. Wooden rods placed on the white sheets to mark the line of crests, measured after totality was passed, gave before totality south 45° west, after totality south 48° west."

The observations of shadow bands by the five experienced observers are more definite and accordant than I recall from the literature of previous eclipses, and they are no doubt extremely valuable. As the bands were observed at least one-half minute before totality and from one-quarter to one-half minute after totality, while the crescent of uneclipsed Sun had great relative length, there seems to be no room for any hypotheses that the shadow phenomena are produced by conditions existing on the Moon. It should be remembered that the eclipse station at Goldendale was located almost precisely on the central line of the shadow. The tangent to the shadow of the Moon drawn at the most advanced point of the shadow would lie in azimuth about south 26° west. This differs fifteen or twenty degrees from the estimated azimuths of the shadow bands. The wave-length of the shadow system was approximately ten inches, and the speed of the advancing shadow system was slow, probably between one meter and three meters per second. All of these facts seem to say that the source of the disturbance lies in the Earth's atmosphere. The phenomenon may possibly proceed from the temperature gradient in the air masses immediately in front of and behind the position of the shadow cone in our atmosphere. The rapid cutting off of the Sun's rays before totality and the reverse process following totality, it is conceivable, may produce temperature or density gradients in the atmosphere favorable to effects upon the solar rays analogous to diffraction.

The reduced size of the Lick Observatory staff, owing to war service, is delaying the detailed study of the eclipse photographs, but it is hoped that the definitive results may appear in print withou undue delay.

The Lick Observatory expeditions of the past have never met with more friendly reception than the people of Goldendale extended. Everyone who had a chance was anxious to assist us, not only positively with advice and material help, but by remaining away when it was thought we were busily engaged with the affairs of the expedition. Our special thanks are due to Mrs. E. R. Morgan, who initiated the proposal that we should use her residence, and whose thoughts were with the needs of the expedition as long as we remained there. We are likewise indebted to Mr. E. R. Morgan and to the other members of the Morgan Milling Company, for many acts of courtesy and assistance. Mr. C. T. Camplan, one of the leading citizens of Goldendale, gave assistance to the expedition on a great many occasions, both before the expedition arrived and during the entire period of residence.

We acknowledge gratefully the assistance afforded by Mr. and Mrs. Zola Brooks, Mr. N. B. Brooks, Mrs. N. R. Norris, Mr. T. Bert Wilson, Mr. T. A. Graham, Agent S. P. & S. Ry., Mr. Robert Ballou, press correspondent, Mr. Bratton, postmaster, Mr. D. Ledbetter, Mr. E. M. Hathaway, photographer, Mr. J. E. Riley and Mr. E. E. Montgomery.

The personal side of our life was exceedingly pleasant, thanks very largely to Mrs. Morgan's thoughtfulness and kindness, and the members of the expedition have only the most agreeable recollections of their experiences at Goldendale.

The announcement of the discovery of the brilliant new star in *Aquila* by Dr. C. P. Olivier at the University of Virginia was brought to us in the late afternoon of Sunday, June 9th, by the newspaper, *The Portland Oregonian.* The first half of Saturday night had been cloudy. The star was looked for and seen on Sunday night, but the spectrographs had all been dismounted and packed for return shipment before the news reached us.